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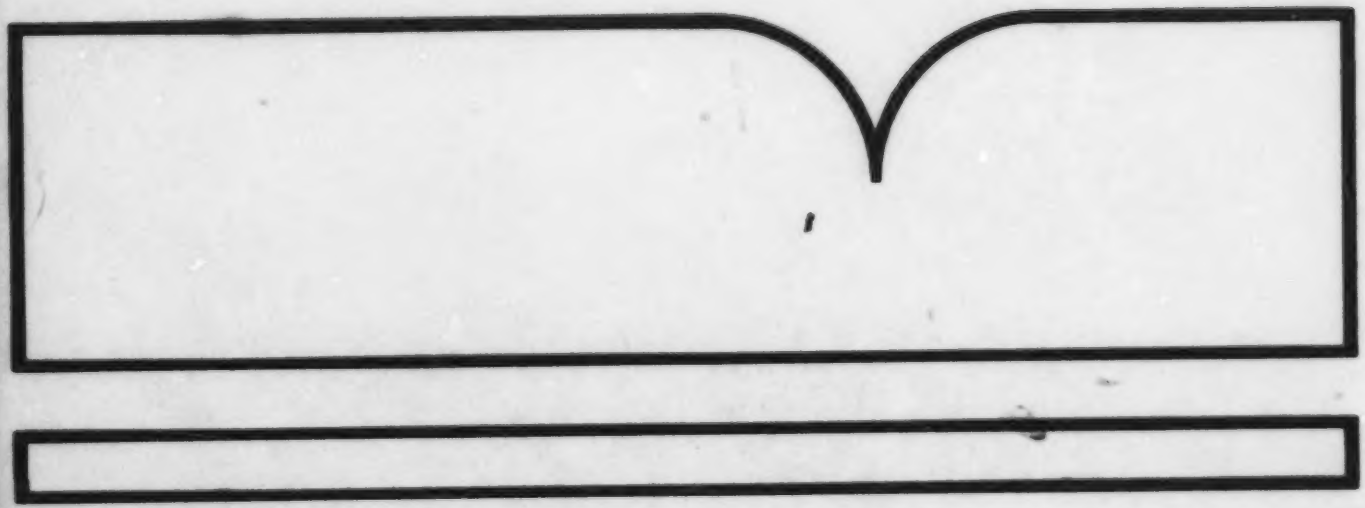

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J.R.Millette, R.L.Boone, M.T.Rosenthal, L.J.McCabe

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THE NEED TO CONTROL ASBESTOS FIBERS IN POTABLE WATER SUPPLY SYSTEMS

J.R. MILLETTE, R.L. BOONE, M.T. ROSENTHAL AND L.J. MCCABE
Health Effects Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, U.S.A.

ABSTRACT

Occupational studies have shown that asbestos is a human carcinogen. Because many inhaled asbestos fibers deposited in the lung are cleared and swallowed, workers are also exposed through ingestion. Of the millions of current and former workers who have been heavily exposed to asbestos, one in ten will die from cancer of the gastrointestinal tract. A number on the order of 1 in 1,000 ingested asbestos fibers penetrate the digestive tract and ingested fibers have been recovered in such tissues as kidney, intestine, liver, and urine. One animal study showed tumor production related to ingestion of asbestos-containing material but, in general, the results of seven animal feeding studies have been inconclusive. A statistically significant relationship between male lung and stomach cancer and female peritoneal, gall bladder, and esophageal cancer and asbestos counts in drinking water was determined in one epidemiology study. Increased rates for male stomach and lung, and female pancreatic cancer related to asbestos in drinking water were reported in another study but possible occupational exposure made it difficult to draw conclusions. Data on excess gastrointestinal cancer among occupational groups has been used to estimate that drinking water containing 300,000 asbestos fibers per liter over a lifetime will result in one additional cancer among 100,000 people.

INTRODUCTION

Asbestos is recognized internationally as a human health hazard. Evidence of adverse health effects associated with asbestos have been reported by numerous researchers in various countries since the turn of the century. Asbestosis, a debilitating disease of the lungs, prompted the establishment of regulations limiting the exposure to asbestos in the workplace throughout the world. In October of 1964, the International Union Against Cancer (UICC) Working Group on Asbestos and Cancer reported that the evidence of an association between exposure to asbestos and malignant neoplasia was substantial (ref. 1). International

concern for the carcinogenic risk of asbestos to humans has continued as evidenced by the several meetings convened by the International Agency for Research on Cancer (IARC) World Health Organization (ref 2,3) on that subject.

ASBESTOS WORKER DIGESTIVE TRACT CANCER

It has been said that one in five workers who have been heavily exposed to asbestos will die of lung cancer. One in ten will die from cancer of the gastrointestinal tract and one in 15 will succumb to mesothelioma (ref. 4).

To those whose responsibility it is to provide for the safety of drinking water, the association between asbestos exposure and gastrointestinal cancer is particularly disturbing. In 1964, Selikoff, Churg and Hammond reported on a study of asbestos insulation workers in which 9 men would have been expected to die from cancer of the stomach, colon, or rectum. In fact, 29 men died of these cancers, an excess of 200% (ref. 5). A number of later studies have also shown a higher observed digestive tract cancer rate than would have been expected (ref. 6-17). The observed to expected digestive system cancer ratios for a number of studies are given in Table 1. A ratio of 1.00 is considered normal and the further from 1.00, the greater the suggestion of effect. Using data on exposures and cancer rates from studies of asbestos miners (ref. 16) and mill workers, (ref. 17) Schneiderman concluded that "increased exposure to inhaled asbestos particles leads to increased digestive system cancer" (ref. 18). Others have also concluded that there is a dose response relationship between airborne asbestos exposure and cancer of the digestive tract (ref. 19). After reviewing the findings in respect to gastrointestinal cancer and occupational asbestos exposure available in 1977, the Safe Drinking Water Committee of the National Academy of Sciences, USA concluded that the data "strongly suggests that ingestion of asbestos mineral fibers can result in an increased risk of cancer of several sites."

Although the combination of cigarettes and asbestos exposure has a tremendous effect on the incidence of lung disease, smoking does not seem to act in synergistic fashion in the digestive system cancer sites except perhaps in the esophagus (refs. 3,20).

PENETRATION OF THE DIGESTIVE TRACT

The connection between the results of occupational asbestos studies and the question of the hazard of asbestos in drinking water is complicated by the fact that the primary route of exposure of an asbestos worker is one of inhalation. However, because it has been clearly demonstrated that a high percentage of inhaled fibers deposited in the lung are cleared and swallowed, (refs. 21-23) the important question is whether asbestos fibers penetrate the gastrointestinal (G.I.) wall and

TABLE 1

Digestive System Cancer in Occupationally Exposed Asbestos Workers (refs. 6-15)

Studies	Observed Deaths / Expected Deaths
Insulation Workers	
Elmes and Simpson (1971)	3.0
Kleinfeld, et al. (1976)	3.9
Selikoff, et al. (1976)	3.1
Selikoff, et al. (1979)	1.7
Factory Workers	
Henderson and Enterline (1979)	1.4
Newhouse and Berry (1979)	
Severe Exposure	2.3
Seidman, et al. (1979)	1.5
Mancuso and El-Attar (1976)	2.7
Mining and Milling	
Kogan, et al. (1972)	
Male Miners	4.3
Female Miners	3.6
Female Millers	19.9
McDonald and Liddell (1979)	
Heavy Exposure	2.9

move to other parts of the body. Clearly, if asbestos fibers do not penetrate the G.I. tract, internal cancers such as those of the kidney in the occupational groups could not have resulted from that route. Some early studies, (refs. 24,25) did not find evidence of digestive tract penetration but the evidence for penetration has increased in recent years to a point where many researchers believe that asbestos fiber penetration of the G.I. mucosa is not a massive occurrence but probably does occur (ref. 26).

Several researchers have reported particulate penetration of the gastrointestinal tissue in animals (refs. 27-30) and ingested fibers have been found in the tissues of rats and a newborn baboon fed asbestos suspended in formula (refs. 31-33). Amphibole fibers were found in the urine and tissues of persons who had ingested drinking water containing the fibers in Duluth, Minnesota (refs. 34,35). Residents on other unpolluted sources did not have amphibole fibers in their tissue or urine. Asbestos fibers have also been found in the urine of a baboon forced to ingest the material (ref. 36) and attapulgite clay fibers have been reported in the urine of a person ingesting large doses for medical purposes (ref. 37). Estimates of the passage rate for asbestiform fibers range from 1 fiber in 1,000 (ref. 34) to 1 fiber in 100,000 (Ref. 32).

WATER EXPOSURE TO ASBESTOS

We know that asbestos is in the drinking water. It is contributed by several sources: erosion of naturally-occurring serpentine rock, discharges of mining and manufacturing activities, fallout from air pollution, and deterioration of asbestos-cement materials. In the United States two areas of natural contamination of water supplies have been studied. In the San Francisco area concentrations of asbestos fibers in the drinking water were reported as high as 130 million fibers per liter. In the Pacific Northwest one water supply has a fiber concentration consistently above 100 million fibers per liter. Only in the water supply for the cities along the western side of Lake Superior has fiber contamination as high as 600 million fibers per liter (ref. 38) been traced to a discharge of a mining activity. No instances of an industrial discharge contaminating a water supply have been documented, although contamination by waste piles has been investigated. Demolition of old buildings and other urban activities have the potential to release asbestos fibers into the air and some of these particles, no doubt, fall into open reservoirs. Asbestos fibers, presumably released from urban activities, have been found in rain water (ref. 39). Asbestos insulation has contaminated at least two water supplies. In one case fibers from sprayed insulation above a holding tank were falling into the water after it had been through filtration treatment. In another case, fibers from asbestos insulation which had been placed at the top of a well for protection against freezing were falling into the shaft. Asbestos-cement products, in general, may not contribute fibers to water supplies since the cement "locks" the fibers in (ref. 40) but it is clearly evident that under some conditions asbestos-cement roofing tiles, building materials, and pipe can corrode and release high numbers of fibers into drinking water (ref. 41,42). Asbestos fiber concentrations over 500 million fibers per liter have been found in cistern drinking waters which use asbestos-cement roofing tiles to collect water. A study of one water supply concluded that the erosion of fibers from an asbestos-cement wall encircling a reservoir caused intermittent high concentrations of asbestos fibers in the drinking water (ref. 41). As much as 500 million fibers per liter have been found in water from some asbestos-cement pipe systems, (ref. 42) while in other asbestos-cement pipe systems no significant numbers have been detected (42,43). A survey of representative water utilities in the United States suggests that 16.5% distribute highly aggressive waters (ref. 44). If these utilities use asbestos-cement pipe, fibers may be added to the water as a result of deteriorating pipe. It is also known that improper tapping (drilling into the pipe to connect a smaller line) of asbestos-cement pipe can result in very high asbestos concentrations in the water. The estimates of asbestos-cement pipe used in the U.S. range from 84,000 (ref. 45) to 200,000 miles (ref. 46).

The distribution of reported asbestos concentrations in drinking waters from the United States as shown in Table 2, indicates that 11% have fiber concentrations, at least on occasion, of over ten million fibers per liter (ref. 42). Caution must be used however in drawing conclusions from this table since it was not a representative sampling but a compilation of available data. A number of systems which were suspected of having a contamination problem were among the first to be analyzed.

TABLE 2

Distribution of Reported Asbestos Concentrations in Drinking Water from 426 Supplies in the United States

Highest Asbestos Concentrations Reported (millions of fibers/liter)	Number of Supplies	Percentage
Below Detectable Limits	121	28.4
Less than One	221	51.9
One to Ten	39	9.2
Greater than Ten	45	10.6
Total	426	100.1

A survey of water supplies in Canada determined that about 5% of the public receive water with fiber concentrations exceeding 10 million fibers/liter (ref. 47). There also was some indication of erosion of asbestos-cement pipe. The results of a small pilot study (10 samples) of asbestos levels in the United Kingdom indicated that the concentrations in distributed water were in the range of 0.4 to 2.2 million fibers per liter (ref. 48). Although the United Kingdom has few locations where natural erosion of asbestos fibers could occur, the erosion of asbestos waste dumps and discharge of asbestos containing effluents may contaminate some water supplies. It has been estimated that 320,000 km of asbestos-cement pipelines have been installed in the United Kingdom, about one-third the total mains. A review of 8 Common Market countries indicated that only in the Netherlands and in Belgium did asbestos cement pipe represent a major part of the material used in distribution systems (Netherlands 45% of the total length, Belgium 75%) (ref. 49).

The exposure data available leave little doubt that a number of water supplies are, or have the potential of being, contaminated with asbestos.

EPIDEMIOLOGY STUDIES

The first study concluding that a statistical association exists between asbestos fiber content in drinking water and the incidence of certain cancers has

just recently been published (ref. 50). Relationships between the chrysotile asbestos content of San Francisco, California area drinking waters were found with white male lung, white female gall bladder and pancreas, and peritoneal cancers in both sexes. Relationships between asbestos fiber count and female esophagus, pleura and kidney, as well as stomach cancers in both sexes were also noted but were of weaker statistical significance. These associations appeared to be independent of income, education, asbestos occupation, marital status, country of origin and mobility. There appears to be a certain consistency of findings when these results are compared with the study comparing cancer incidence for Duluth, Minnesota and Minneapolis and St. Paul, Minnesota (ref. 51) and a study of mortality in Quebec, Canada where high concentrations of asbestos in the drinking water have been known to exist for some time (ref. 52). Male stomach and female pancreatic cancers were significant in both earlier studies and when included as analysis sites in either study, male lung and peritoneal cancers were also suggestive (ref. 50).

In Connecticut, no association between the use of asbestos-cement pipe and elevated cancer risk could be found (ref. 53). Analysis of the water in all the towns, however, did not show that high concentrations of fibers were being eroded from asbestos-cement pipes.

A preliminary report on the study of the effects of asbestos in drinking water on cancer incidence by census tract in the Pacific Northwest of the United States did not show any association between fibers in the drinking water and cancer of the colon, stomach, kidney, or total alimentary tract (ref. 54). Some generalized assumptions had to be made in assessing cancer risks at this stage in the study. More specific studies in this area are still underway. The study population ingests relatively high (greater than 100 million fibers/liter) concentrations of naturally eroded asbestos fibers which are all under 3 micrometers in length. This represents a rather unique situation in which the effect of short fibers is being investigated. As can be seen in Table 3, fibers from the deterioration of asbestos-cement materials and even natural erosion in other areas are generally longer than those found in the Pacific Northwest. There seems to be some basic agreement that fiber size and shape play an important role in tumor potential.

ANIMAL STUDIES

Although asbestos and other fibrous materials injected or implanted into animals have resulted in the production of malignant neoplasms, animal studies of ingested asbestos have not thus far been very helpful in determining the health risk of asbestos in drinking water. The Safe Drinking Water Committee of the National Academy of Sciences, U.S.A. reviewed the animal toxicology results available through 1976 (ref. 55). They reported that four studies did not show evidence of increased cancer incidence by asbestos ingestion (refs. 22,25,56,57).

TABLE 3

Fiber Size Characteristics of Some Drinking Water

Description	Mean Value Length*	Width*	Aspect Ratio**	Max. Length*
Chrysotile				
A/C Pipe System, FL	4.6	0.035	140:1	60
A/C Pipe System, SC	4.0	0.055	98:1	80
Natural Erosion, WA	0.9	0.034	25:1	3
Natural Erosion, CA	1.3	0.04	39:1	10
Cistern-Asbestos tile roof	2.3	0.04	62:1	25
Amphibole				
Lake Water, MN	1.7	0.18	8:1	18

*in micrometers
**Length/Width, unitless

One study showed the development of 12 malignant tumors in a group of 50 rats fed asbestos-containing filter material (ref. 58). The NAS group felt that none of the studies could be considered adequate under modern constructs of chronic toxicity testing and that the matter was unresolved. The results of two limited asbestos feeding studies were reported in 1977 (ref. 31). Although some cancers were reported, the data are not considered conclusive because of the limited number of animals. One researcher has recently reported finding tumors "in hamsters that drank water containing fibers of naturally crystallized amosite asbestos from South Africa" (ref. 59), but full details have not been published.

A large scale asbestos feeding study (ref. 60) is currently under way with rats and hamsters. Preliminary results do not show increased mortality among hamsters ingesting asbestos but, final results are not expected until 1981. The results of the large scale feeding study will undoubtably provide important data. However, as the National Academy of Sciences (ref. 55) cautioned; "negative results may be interpreted as indicating either the absence of an effect of ingested asbestos or as further proof that the animal model was not valid to start with." If certain animal species do not get cancer, the excess gastrointestinal cancer among the asbestos insulation workers must still be explained.

INGESTED ASBESTOS A HEALTH HAZARD?

It would be impossible to discuss and reference all the articles that have been published concerning asbestos and health. A recent computer search of the medical literature listed over 600 entries on the subject. Reference 26 lists 810 in its bibliography. The citations presented here are pertinent to the under-

standing of the scientific arguments for controlling asbestos in drinking water.

When an advisory committee of the International Agency for Research on Cancer, meeting in 1972, considered whether there was evidence of an increased risk of cancer resulting from asbestos minerals present in water, they concluded that "such evidence as there is does not indicate any risk" (ref. 2). However their conclusion can hardly be taken as a categorical denial of risk, but rather reflected the inconclusive character of the evidence then available (ref. 55). The question of ingested asbestos has remained argumentative since then, although the reputation of asbestos as a human carcinogen has suggested caution in exposure situations. In June of 1973, when the U.S. Environmental Protection Agency announced that high concentrations of asbestos fibers had been found in the drinking water of Duluth, Minnesota, the agency also said that "prudence dictates that an alternative source of drinking water be found for very young children" even though it had not made any decision as to the safety of ingested asbestos (ref. 61).

Also in 1973 the Center for Science in the Public Interest petitioned the U.S. Environmental Protection Agency and 6 legislators to request a ban on the use of asbestos-cement pipe in water systems. The Center said that "there is ample reason to believe that ingestion of the major varieties of asbestos leads to increased risk of gastrointestinal cancer" (ref. 62). A committee sponsored by the American Water Works Association, however, concluded in 1974 that "calculations comparing the probable ingestion exposure in occupational groups to that likely to occur as a result of ingestion of potable water from asbestos-cement pipe systems suggests that the probability of risk to health from the use of such systems is small--approaching zero" (ref. 63).

A report prepared for the Commission of European Communities in 1977 concluded "at this moment there is no evidence that there exists any increased health risk from asbestos fibres present in drinking water... experience from drinking water authorities has not shown any relationship between the prevalence of gastrointestinal tumors and the presence of asbestos in drinking water" (ref. 64). Now that some evidence of a relationship has been published (ref. 50) the Commission will need to update their conclusions. Another report in 1977 by the International Agency for Research on Cancer was more cautious in its conclusions about asbestos in drinking water. It contained the conclusion: "At present, it is not possible to assess whether there is a level of exposure in humans below which an increased risk of cancer would not occur" (ref. 3).

During the last few years a number of countries have set limits on the use of asbestos as a means of reducing asbestos-related disease. Sweden has eliminated most of the asbestos used in the country. The United Kingdom has greatly restricted the importation and use of blue asbestos, crocidolite. The Minister of Social Affairs, The Netherlands, published a directive which forbade all usages of crocidolite, although some was still allowed in the making of larger asbestos-

cement pipe. In the U.S.A. hairdryers containing asbestos were recalled, a symposium to draw together information on asbestos substitutes was sponsored by the government, and a large scale cleanup of sprayed-asbestos insulation is underway in school buildings.

CONCLUSIONS AND DISCUSSION

At this moment in 1980, there are several reasons to consider controlling asbestos in drinking water. 1) There is now some direct human evidence of a relationship between asbestos in drinking water and increased cancer risk. 2) There is now abundant evidence that ingested asbestos fibers penetrate the digestive tract which requires that the documented excess gastrointestinal cancers in asbestos workers be considered seriously. 3) There is now a general attitude in a number of countries that the only effective way of preventing asbestos-related disease is to drastically restrict the use of the material.

If asbestos is to be controlled then what level of asbestos in the drinking water is considered hazardous to health? At what concentration is action required? The recommended occupational limit of 0.1 optically counted fiber per cubic centimeter of air was used to estimate an equivalent drinking water exposure of between 4 and 15 million asbestos fibers of all sizes per liter (ref. 65). Data on excess gastrointestinal cancer and peritoneal mesotheliomas from three (refs. 8,12,14) occupational studies were used with exposure data and conversion factors to estimate that the ingestion of 300,000 asbestos fibers per liter of water over a 70 year lifetime would result in one additional death per 100,000 people, one additional death per 200,000 if only the G.I. cancer is considered (ref. 66). A quick analysis of nationwide U.S. cancer risk shows that this value is not unreasonable. If 10% of the U.S. Population is exposed to an average of 20 million fibers per liter in their drinking water, 70,000 excess gastrointestinal cancer deaths would be predicted in 70 years. That is about 1000 per year over the entire population. There are about 100,000 digestive system cancers in the U.S. each year. Peritoneal mesothelioma is a rare cancer not reported in the general population and perhaps should not have been included in the estimate of a waterborne asbestos hazard level. However it is possible that many peritoneal mesotheliomas are misdiagnosed in the general population as evidenced in Selikoff's review of death certificates of insulation workers (ref. 14). Among the asbestos workers, mesothelioma was found to be misdiagnosed 30% of the time.

An asbestos fiber concentration of 300,000 fibers per liter is measurable in most drinking waters with current state of the art techniques but precision between laboratories at this concentration has not been validated. Some drinking waters with high turbidity contain too many interfering particles to achieve this low level of detection with the present method (ref. 67).

While issues of asbestos definition and hazardous fiber size must still be addressed, it is suggested here that sufficient reason exists for the water supply community to make controlling of asbestos in all water supplies an official policy. Action should be taken to remove asbestos fibers in source water by filtration and restrict the use of asbestos-cement materials to those situations in which they do not come in contact with corrosive water.

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